

COUPLED MODE SURFACE PLASMON RESONANCE SENSOR: IN SITU DETECTION OF HUMIDITY WITH STARCH BIOFILM

Jonnalagadda Padmarani

Department of Physics (Opto Electronics), Osmania University, TS, India

Abstract:

An environment friendly coupled mode surface plasmon resonance sensor structure with starch biofilm as sensing element for humidity detection of environment is fabricated and demonstrated. The surface plasmon resonances were created using PVC layer fabricated between silver and starch biofilm on a rectangular prism. The analyses of fabricated sensor have been done by both wavelength and angular interrogation methods. The proposed sensor has maximum sensitivity 0.45 nm/%RH in wavelength interrogation method and 0.09°/%RH in angular interrogation method. Here the variations in humidity of environment, changes the refractive index of starch biofilm and hence in the surface plasmon resonances. Also, the proposed sensor shows a linear variation in resonance wavelength and resonance angle with respect to the variation in humidity of environment.

INTRODUCTION

There has been great progress in solar cell efficiency, recently, as shown in Figure 1. After a long period of no improvement, the past two years have witnessed a surge to 28.8% efficiency [1] in the flat-plate, single junction, record. This is to be compared [2] with the Shockley-Quasar [3] limit, 33.5% efficiency. The idea that increasing light emission improves open-circuit voltage seems paradoxical, as it is tempting to equate light emission with loss. Basic thermodynamics dictates that materials which absorb sunlight must emit in proportion to their absorptive. At open circuit, an ideal solar cell would in fact radiate out from the solar cell, a photon for every photon that was absorbed. Thus the external luminescence

efficiency is a gauge of whether additional loss mechanisms are present.

At the power optimized operating bias point, the voltage is slightly reduced and 98% of the open-circuit photons are drawn out of the cell as real current. Good external extraction at open circuit comes at no penalty in current at the operating bias point. On thermodynamic grounds, Ross derived [4] that the open circuit voltage is penalized by poor external luminescence efficiency hext as: $qV_{OC} = qV_{OC} - kT \ln h$ (1) where hext is the probability of an internally radiated photon eventually escaping from the front surface of the cell. Equation (1) can be derived through the detailed balance method [2] of Shockley and Queisser (SQ). M. A. Green already inferred

[5] the external luminescence yield, next, of all the different historical solar cell materials, from their respective record $\{VOC_{ideal} - VOC\}$, employing eq'n. (1). As solar efficiency begins to approach the SQ limit, the internal physics of a solar cell transforms. Shockley and Queisser showed that high solar efficiency is accompanied by a high concentration of carriers, and by strong fluorescent emission of photons. In a good solar cell, the photons that are emitted internally are likely to be trapped, re-absorbed, and re-emitted, leading to "photon recycling" at open-circuit. This leads to a very different physical picture of high

efficiency solar cells, >26% efficiency, as illustrated in Figure 2. To resolve the paradox of why external luminescence is good for solar cell efficiency, there are a number of different explanations:

1) Good external luminescence is a gauge of few internal loss mechanisms. At open circuit, an ideal solar cell radiates a photon for every absorbed photon. When electron-hole pairs recombine non-radiatively or when photons are absorbed without generating photocarriers within the active part of the device, both the external luminescence efficiency and the cell efficiency decrease.

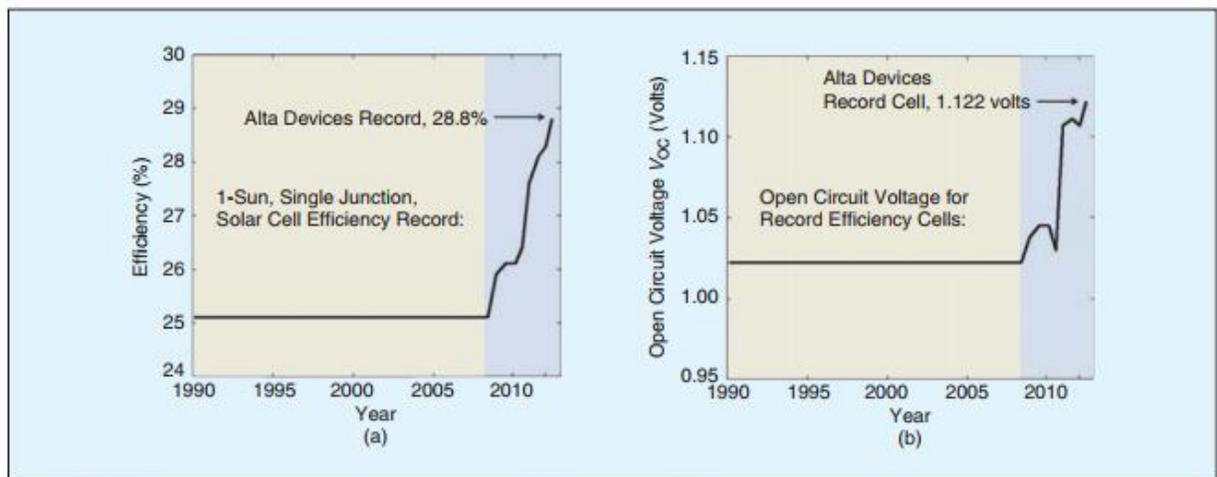


Figure 1. (a) The single junction, 1-sun, efficiency record, historically. (b) The open circuit voltage of the record solar cells.

2) External emission of photons into free space is unavoidable. All other losses can, in principle, be eliminated. Thus the total losses are at their very least, when external emission is the only loss mechanism. Maximum external emission is minimum total losses, which leads to the highest efficiency.

3) In un-textured cells, good external luminescence requires recycled photons, and re-absorption. Internal reabsorption recreates the electronhole pair, effectively extending the minority carrier lifetime. The longer lifetime leads to a higher carrier density. Free energy, or voltage, increases with the logarithm of density.

4) The solar cell and the light emitting-diode are equivalent, but reciprocal devices. Just as external emission leads to the most efficient light-emitting-diode, the most efficient solar cell maximizes external emission.

5) External luminescence is sometimes used as a type of contactless voltmeter, indicating the separation of quasi-Fermi levels in the solar

material. This is sometimes employed as a contactless, quality-control-metric, in solar cell manufacturing plants. In this viewpoint, it is tautological: Good external luminescence actually IS good voltage, and therefore good efficiency. This is the preferred explanation for the paradox: Good external luminescence IS good voltage

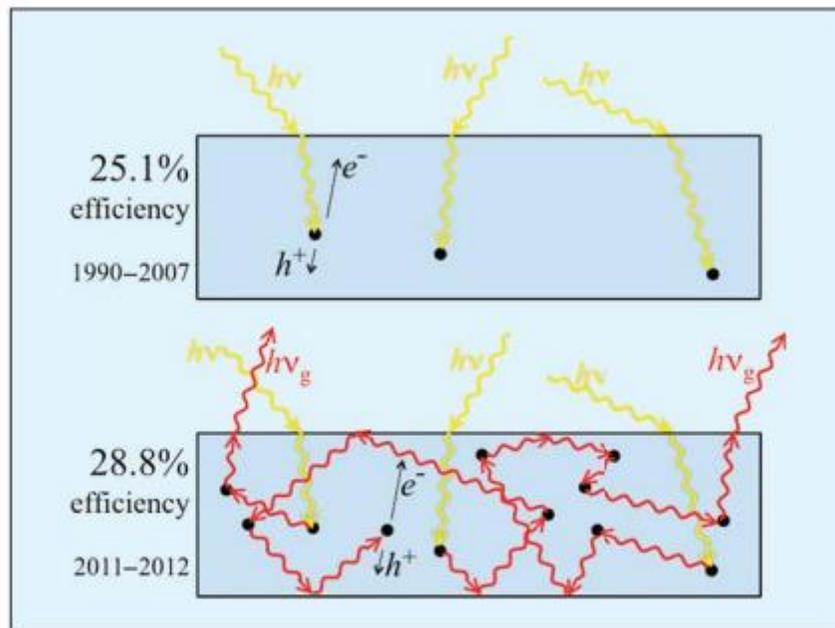


Figure 2. The physical picture of high efficiency solar cells, compared to conventional cells. In high efficiency solar cells, good luminescent extraction is a requirement for the highest open circuit voltages. One-sun illumination is accompanied by up to 40-suns of trapped band-edge luminescence, leading to the maximum external fluorescence efficiency.

ZnO nanorods were prepared by a simple chemical precipitation method in the presence of capping agent PVP. X-Ray Diffraction result indicates that the synthesized undoped ZnO nano rods have wurtzite hexagonal structure without any impurities. It has been seen that the growth orientation of the prepared ZnO nano rods were [101]. XRD analysis revealed

that the nanorods having the crystallite size 49 nm. The SEM image confirmed the size and shape of these nanorods. The diameter of nanorods has been found that 1.52 μm to 1.61 μm and the length of about 4.89 μm . It has also been found that at room temperature ultra violet (UV-Vis) absorption band is around 355 nm (blue shifted as compared to bulk).

Electroluminescence (EL) studies show that emission of light is possible at very small threshold voltage and increases rapidly with increasing applied voltage. It is seen that smaller ZnO nanoparticles give higher electroluminescence brightness starting at lower threshold voltage. The brightness is also affected by increasing the frequency of AC signal.

In recent years One dimensional nanostructure materials like nanorods, nanowires, nanotubes have received more attention due to their remarkable properties. These properties are very useful in all fields like optoelectronics, electronic nanodevices etc.[1,2]. To understand the basic phenomena of quantum size effect on electrical, optical, mechanical and magnetic properties, some important semiconductor nanomaterials like GaN[3], CdS[4], Si[5], SnO₂[6], TiO₂[7], ZnO[8,9] and CeO₂[10-13] have been widely studied. Among them ZnO nanomaterials have been chosen because of their remarkable properties like wide and direct band gap (Eg- 3.4 eV) and large exciton binding energy (60 meV). Its wide band gap and large exciton binding energy UV lasing action is possible at room temperature [14]. In ZnO, due to the extreme large binding energy, the excitons are thermally stable. All these reasons ZnO has significant advantages in optoelectronic applications like ultraviolet (UV) lasing media [15]. The wide and direct optical energy band gap of 3.37eV is large enough to transmit most of the useful solar radiation for ZnO. It is an n-type semiconductor which belongs to II-VI group. It is very useful for transparent electrodes in flat panel displays,

solar cells and promising material for short wavelength light emitting devices [16-18]. ZnO epitaxial films and nanostructures have been mostly studied for applications in UV-emitters, solar cells, gas sensors, varistors and surface electro-acoustic wave devices[19]. Low dimensional nanostructures are now being extensively used in the field of advanced devices.

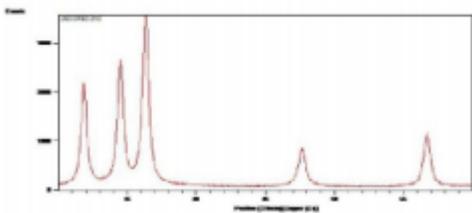
For electroluminescence devices, ZnO is one of the most widely investigated phosphor. The EL performance of alternating current devices is a strong function of the crystallinity of the phosphor interface properties, space charge in the phosphor, the nature of the luminescent centers and their coordinates in the host crystal lattice

For the synthesis of nanomaterials there are various methods like, chemical vapour deposition[21], laser ablation[22], vacuum arc deposition[23], sputtering[24] and hydrothermal process[25,26]. But most of these fabrication techniques have complex steps, which require extremely sophisticated instruments, precise experimental setup and extreme experimental conditions. Hence, it is important to develop a very simple method to fabricate ZnO nanorods in laboratory environment. The chemical precipitation method provides a better route to fabricate multidimensional nanostructure in a very large scale. This technique is inexpensive, which does not require any complicated processing or huge infrastructures.

Present studies have been undertaken to synthesize ZnO nanorods of various sizes and investigated their electroluminescence

RESULTS AND DISCUSSIONS

A typical XRD pattern of the prepared nano rods is shown in fig.1. The pattern obtained is indexed with hexagonal unit cell structure with wurtzite structure (JCPDS Card no.36-1451). The observed relative peak intensities and interplaner spacing has been compared to that of their standard values which is given in table 1. All peaks of the obtained product correspond to the hexagonal wurtzite structure of Zn which is studied by many researchers. In fig.1, the detected peaks are at 2θ values of 31.8384°, 34.4937°, 36.40840°, 47.57920°, and 56.65420° corresponding to the following lattice planes [100], [002], [101], [102], and [110]. It has been observed that there is a small difference in the relative peak intensities of the lattice planes [100] to [002] and in the d-spacing of different peaks. Also, it has been seen that the XRD patterns of the nano rods are considerably broad because the crystals are randomly arranged or have low degree of periodicity. Furthermore no impurities were found in XRD pattern. This result shows that high purity hexagonal ZnO nano rods could be obtained by this chemical method



CONCLUSIONS

ZnO rods with diameter 1.52 μm -1.61 μm and length of 4.89 μm respectively obtained by SEM have been successfully prepared by a simple chemical precipitation method at room temperature. In this sample preparation method zinc acetate dihydrate was used as a precursor and poly vinyl pyrrolidone was used as a capping agent. The XRD patterns obtained confirms the formation of wurtzite hexagonal ZnO nanostructures without any impurities. The XRD studies of these nanorods revealed that their average size is about 49 nm for undoped ZnO calculated by Debye Scherrer formula. Further, the UV absorption at \approx 355 nm is found which is blue shifted; energy band gap of ZnO is calculated as 3.4eV from UV-Visible absorption spectra. Hence, it is concluded that in the presence of deionised water as solvent, the size of ZnO rods is in micro range. EL studies have shown that light emission starts from undoped ZnO nanorods at lower threshold voltage and higher EL intensity is obtained in case of smaller particles. Thus high efficiency EL devices for display and lightening can be fabricated by using small size of undoped ZnO nanorods. This study provides new approaches to change the optical properties which can be used as a strong tool for further optoelectronic applications.

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